Application of Prompt Gamma Activation Analysis (PGAA) to Inorganic Photochromic Host Materials*

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Prompt Gamma Activation Analysis (PGAA) is a nondestructive radioanalytical method capable of rapid, in situ, simultaneous, multi-element analysis involving the entire periodic table from hydrogen to uranium. Gamma rays produced instantaneously following neutron capture on a sample provide a unique energy and intensity signature for nearly every element. The gamma-ray spectra can span the range of 10 MeV and are often complex, but recent advances with Compton-suppressed Ge detectors and guided neutron beams have made PGAA more quantitative than in the past. A new PGAA gamma-ray library has been developed at Budapest that greatly improves the precision of the technique.

The measurements discussed here were performed at the 10 MW Budapest Research Reactor, Hungary. A beam of low-energy neutrons is transported 35 m from the reactor core by a slightly curved neutron guide made of glass coated with a nickel reflector. At the target the thermal-equivalent flux of the beam is $\sim 2.5\times 10^{6}$ $cm^{-2}s^{-1}$. The beam is collimated to an area 2×2 cm and samples were placed in FEP Teflon bags. The detector system consists of a high-purity Ge detector surrounded by a BGO scintillator to reject Compton scattered photons. The detector system is shielded against neutron- and gamma-radiation background. A baseline suppression of ~6 was achieved at 1332 keV.

Spectra were collected in a 16,000 channel Canberra S100 MCA. Energy and efficiency calibrations were performed with well-known gamma rays from radioactive sources and (n,γ) reactions. The spectra were evaluated with *Hypermet PC* a complex γ-spectrum evaluation program developed at Budapest.

One of the most important aspects of photochromic materials is that of dopant species in the lattice of the host material. Some of the most common dopants include transition metal oxides such as those of iron, chromium, and vanadium, as well as other metal ions. The exhibited degree of photochromism is a function of which metal ions are in the lattice of the host material and their concentration. By identifying and correlating them with the photochromic performance, workers can use the data to both model the processes in which the dopant metal ions are involved and to design materials with different properties.

PGAA analysis has been used to study dopant impurities in ZnO, HfO_2, and CaF_2. These three inorganic materials are representative of oxide and halide materials that exhibit photochromism, their photochromic properties being heavily dependent on the inclusion of other metal ions at extremely low concentration levels. The also provide and opportunity to look at a wide array of contaminant elements that exhibit a varying degree of complexity in their chemistry. A summary of the results is shown in the following table.

Summary of Analysis of Photochromic Host Materials Using PGAA

CaF_2 (Reagent grade, Baker and Adamson)
    Ca-54.3(9)%, F-44.4(19)%, Al-0.66(7)%, Cl-0.150(3)%, Na-0.040(9)%
ZnO (Mallinckrodt)
    ZnO-100%, Cd-5.1(3) ppm
HfO_2 (98%, Aldrich Chemical Co,)
    No detectable impurities

Footnotes and References

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